SECTION 5
DETERMINATION OF COUPLING MECHANISM

5.1 INTRODUCTION

With reference to Section 4, interference mitigation measures will be ineffective unless the correct interference coupling mechanism (radar transmitter spurious emissions or earth station front-end overload) is identified. This section describes methods by which the interference mechanism may be determined, so that appropriate mitigation measures may be implemented as reliably as possible. It should be noted that the tests and measurements required to determine the interference mechanism are not necessarily easy to perform, even if the earth station facility has access to the necessary test equipment (a spectrum analyzer and digital oscilloscope are recommended, at a minimum).

Commercially available RF front-end bandpass filters (passband of 3700-4200 MHz) for earth stations typically cost a few hundred dollars and can be installed relatively quickly. Installation of such a filter <u>ahead</u> of the first LNA/LNB/LNC in the earth station RF front-end is recommended as a first step at an earth station which is experiencing interference. If the only interference mechanism is front-end overload which is occurring outside the 3700- to 4200-MHz band, then the filter should mitigate the problem. (It should be noted that the presence of front-end overload does not necessarily mean that the overloading signal is outside the earth station's band, but under United States spectrum allocations (see Section 2) it would not be expected that a sufficiently strong signal, and particularly not a radar fundamental, would occur in the 3700-to 4200-MHz portion of the spectrum. No case of in-band front-end overload is known.)

It is also possible for front-end overload interference and radar spurious emission interference to occur simultaneously. In that case, installation of a bandpass filter on the earth station will only eliminate the front-end overload interference component; the station will still experience interference effects due to the radar spurious emissions in the 3700-to 4200-MHz band. Because of this possibility, the installation of a bandpass filter on the earth station <u>ahead</u> of the LNA/LNB/LNC is recommended before tests for radar spurious emission interference are attempted. If no such filter is installed, then the absence of earth station front-end overload must be verified through tests described below.

Finally, it should be noted that an earth station front-end amplifier which also incorporates a mixer/downconverter (LNB or LNC) may generate undesired products in the 3700- to 4200-MHz band when it is in an overload condition, as shown in Section 3. These products may be easily mistaken for radar spurious emissions in the earth station band. Thus, it is critical that the possibility of front-end overload be eliminated by installation of a front-end bandpass filter before tests for spurious emissions are performed.

5.2 MEASUREMENT PROCEDURES

Determination of Front-End Overload in an Earth Station

There are several steps in the process of determining whether or not front-end overload is occurring in an earth station. The first and most obvious step is to physically examine the

RF front-end of the system, usually at the antenna, and determine if any preselection already exists. It is important not to be misled by schematic diagrams, which may indicate the presence of filters which may not have actually been installed, or by narrow frequency ranges which are specified on an amplifier case (e.g., "3.7-4.2 GHz"); the actual amplifier response may be much wider than the label indicates. If RF bandpass filtering <u>ahead</u> of the first preamplifier is verified as being present, then it is very unlikely that the coupling mechanism is front-end overload. If no such filtering is present, then such a filter should be installed. If the installation results in elimination of the problem, then the mechanism is probably front-end overload.

If a bandpass filter for the earth station is unavailable, or for any other reason the presence of front-end overload must be independently verified, then the following measurement procedure can be performed through the front-end of the earth station during an interference event. The goal of this measurement is to determine the extent, if any, to which the amplifier is gain-compressing when energy from the radar is received. In order to document this effect clearly, it is necessary to simultaneously monitor the radar energy at the radar fundamental frequency, as well as the response of the earth station to that energy. A block diagram for the hardware arrangement to used in this test is shown in Figure 21.

With reference to Figure 21, this test is performed with the antenna feed horn connected directly into the earth station's front-end amplifier (LNA/LNB/LNC). THERE SHOULD <u>NOT</u> BE ANY BANDPASS FILTER AHEAD OF THE LNA/LNB/LNC DURING THIS TEST. The signal out of the amplifier is then split into two paths. One side of the split is sent to a spectrum analyzer, and the analyzer video output is in turn routed to one channel of an oscilloscope, [15] The analyzer should be tuned to the equivalent preamplifier output of the radar fundamental frequency (see Identification of the Radar, below), and the analyzer frequency span should be set to O Hz. (If two or more radar fundamentals are produced, any one of them will suffice.) The analyzer IF bandwidth should be set to 1 MHz, and analyzer trace sweeping should be suspended.

The other side of the split is routed to the earth station receiver, and the receiver's IF output is routed to a second channel of the oscilloscope. The oscilloscope should be triggered from the radar pulse train coming out of the spectrum analyzer. Thus, both the radar pulse train and the earth station response to that pulse train maybe simultaneously observed on the oscilloscope. If the radar is overloading the earth station front-end, then gain compression should be observed on the IF trace when pulses from the radar are observed on the other oscilloscope trace. Examples of such responses are shown for an LNA and an LNB in Figures 22-25.

A variation on this technique can be implemented on an antenna that incorporates two cross-polarized feeds: install a bandpass filter <u>ahead</u> of the preamplifier on one feed. If

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[15] **Documentation of these measurements is important. Either a digital oscilloscope that can transfer data to a magnetic medium or an analog oscilloscope with a camera can be used for this purpose.**

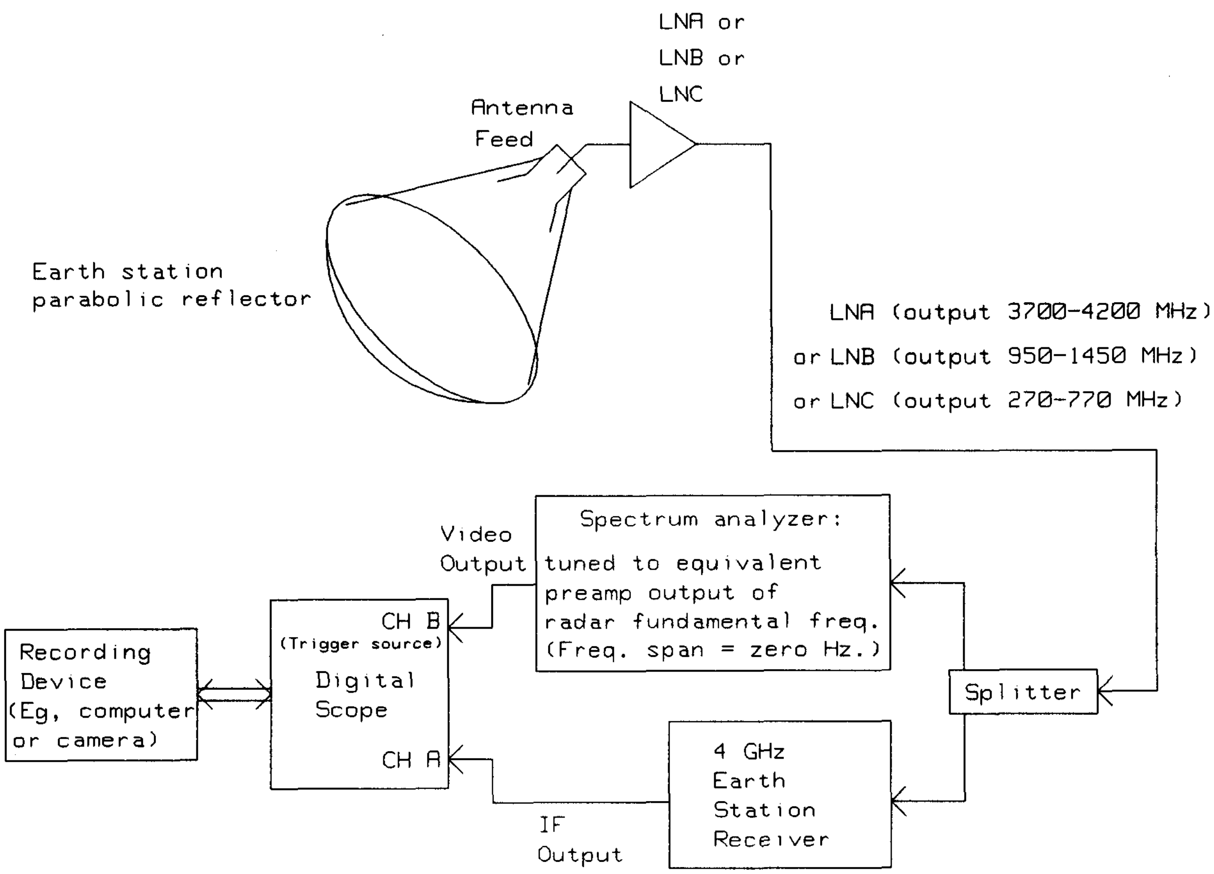

Figure 21. **Block diagram for determination of interference coupling mechanism. Characteristics of either front-end overload or radar spurious emissions are observed in coincidence with radar pulses.**

interference subsequently occurs on the unfiltered feed but not on the filtered feed, then the problem is earth station front-end overload. As a caveat, however, it should be noted that interference may be polarization-dependent, and the cross polarization between feeds can unintentionally produce a filtering effect of its own. So it is critical, if this technique is attempted, that both feeds are known to have previously been affected by the interference simultaneously.

Simultaneous Occurrence of Front-End Overload and Spurious Emission Interference

As stated at the beginning of this section, it is entirely possible for both earth station front-end overload and radar spurious emission interference to occur simultaneously. This would be the case if a radar produced strong spurious emissions at the earth station's center frequency, while the earth station was being operated with an unpreselected front-end. However, before the spurious emission interference problem can be addressed, the possibility of front-end overload must first be eliminated by installing an RF filter on the earth station.

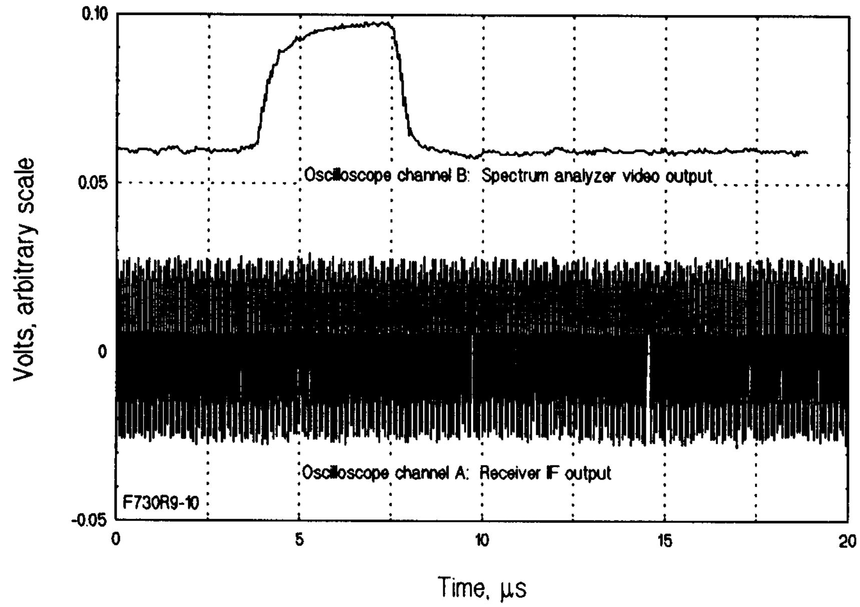

Figure 22. Channels A and B of oscilloscope when test arrangement of Figure 21 is used and LNB front-end is not overloaded. Note that time axis is much faster, due to faster expected recovery time of LNB.

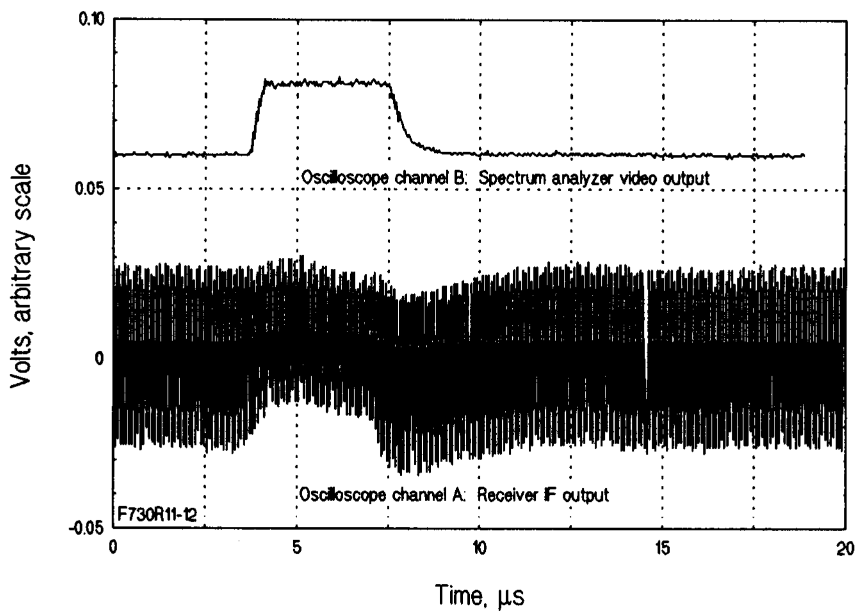

Figure 23. **Channels A and B of oscilloscope when test arrangement of Figure 21 is used and LNB front-end is overloading. Note faster recovery time of LNB than of LNA, (interval the same as pulse width).**

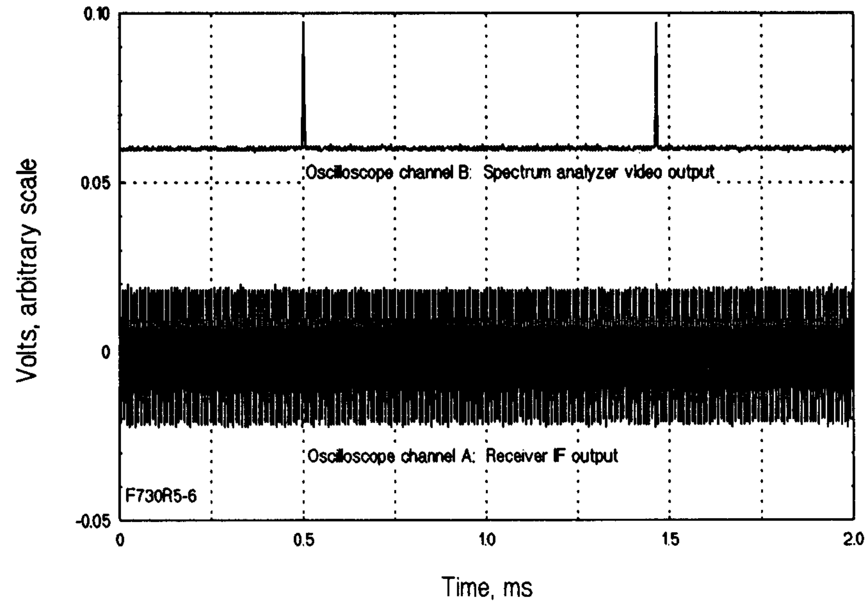

Figure 24. **Channels A and B of oscilloscope when test arrangement of Figure 21 is used and radar pulses are not overloading LNA front-end.**

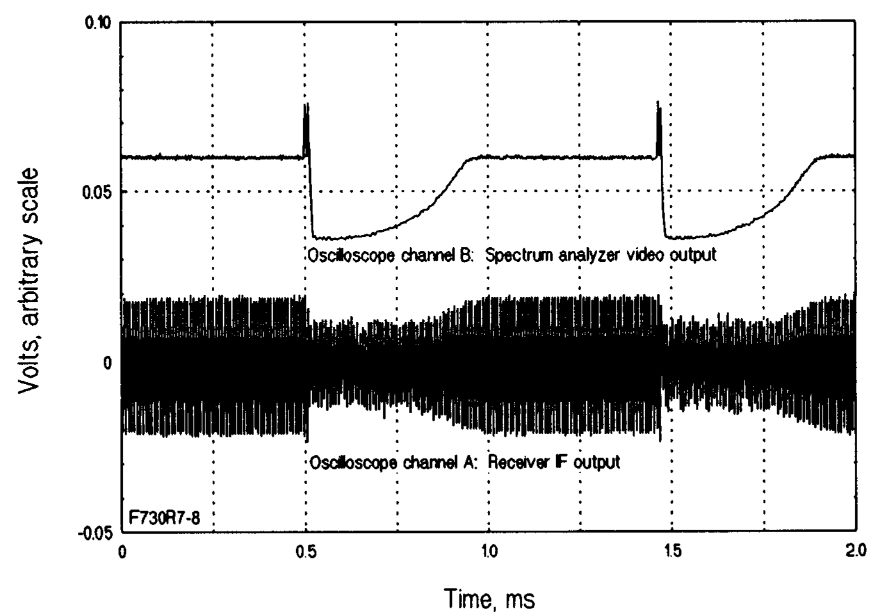

Figure 25. **Channels A and B of oscilloscope when test arrangement of Figure 21 is used and front-end LNA is overloading. Note long LNA recovery interval relative to the radar pulse width.**

Determination of Radar Spurious Emissions in an Earth Station

If tests for front-end overload are negative or interference persists when a 3700- to 4200-MHz bandpass filter has been installed ahead of the first RF amplifier in the earth station, then the interference is probably occurring as a result of spurious emissions in the earth station band.

It must be emphasized that, if the tests for radar spurious emission interference are to utilize unpreselected earth station RF front-ends, as shown in Figure 21, then the possibility that interference is caused by front-end overload must be eliminated before these tests are conducted. While the use of a bandpass filter on the earth station front-end is not absolutely required under these circumstances, the presence of such a filter during the tests increases the confidence that no front-end overload is occurring.

The observations may be accomplished in two ways. One method uses the same block diagram arrangement as shown in Figure 21 (but preferably with a bandpass filter inserted ahead of the LNA/LNB/LNC). The result will be to observe the radar spurious emission pulses superimposed on the desired signal, as shown in Figure 26. The spurious emission radar pulses will usually be observed as pairs of high leading and trailing edges ("rabbit ears"); the time-domain spacing will be the same as the nominal pulse width. It is also possible for spurious emissions to appear as noise-like pulses. A disadvantage to this method is that the presence of the desired earth station signal may have the effect of masking the radar spurious emissions.

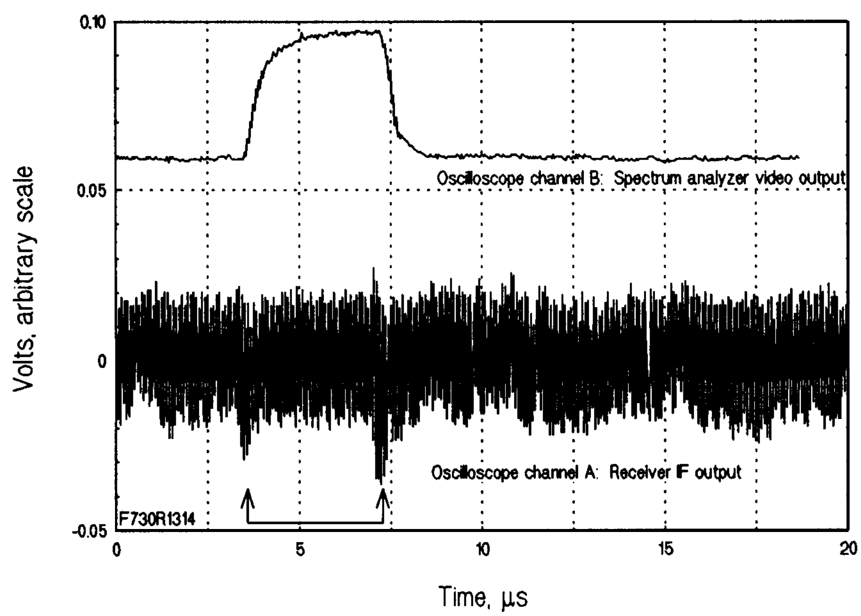

Figure 26. Channels A and B of oscilloscope when test arrangement of Figure 21 is used and spurious emissions occur at received frequency. Desired signal must be eliminated to perform this test.

The second observation technique eliminates the desired signal, thus reducing possible masking of the radar spurious emission pulses. With reference to Figure 21, this is accomplished by substituting an omnidirectional antenna for the earth station parabolic antenna (and again, preferably with a bandpass filter inserted ahead of the LNA/LNB/LNC). The omnidirectional antenna must have a frequency response of at least 2700- to 4400-MHz. This method may be most practical if the earth station has a spare receiver system already available, to which the omni antenna can be attached.

If radar spurious emissions are established as causing interference to an earth station, then the radar that is involved must be identified. The radar spurious emission levels must be quantified so that steps can be taken to resolve the problem.

Identification of the Radar

Identification of the radar can be achieved most easily if the parameters of pulse width, pulse repetition rate, fundamental frequency or frequencies, beam scanning technique, and beam scanning interval are obtained. (Direction finding is desirable but is often difficult for personnel who are unfamiliar with such techniques.) Measurements of radar emission parameters can be performed with a spectrum analyzer and an oscilloscope attached to the analyzer's video output. It is critical that the measurement system be deselected, so that front-end overload does not affect the measurements. An omnidirectional antenna should be used, because it will probably provide more gain in the direction of the radar than the earth station's dish antenna will provide.

The radar's fundamental frequency may be determined by sweeping the analyzer as rapidly as possible across the 2700- to 4400-MHz portion of the spectrum, using the widest possible IF bandwidth and positive peak detection with a maximum hold trace mode. The fundamental frequency of the radar should become roughly defined after a few rotations of the radar's main beam. The analyzer should then be tuned to the measured fundamental frequency and a narrow frequency span (about 50 MHz) should be selected. After a few more rotations, the center frequency should be well-defined. The analyzer should then be re-tuned to the radar center frequency again, and the frequency span should be adjusted to O Hz. In this mode, the spectrum analyzer becomes a slow-motion oscilloscope.

The sweep time should be set to about 60 s, and then the time trace of the radar's beam scanning will become visible. If the radar is rotating mechanically, the time trace will be repetitive and the rotation interval can be read directly off the analyzer screen using a delta marker function. If the radar is a phased array system, or if it is a three-dimensional system that scans elevation as well as azimuth, the time trace will be irregular but a typical time interval between visitations of the main beam may be estimated. In any event, at this point the radar's fundamental frequency or frequencies, beam scanning technique, and rotation interval, if any, should have been acquired.

Next, a storage oscilloscope should be attached to the analyzer's video output. A time scale of several microseconds per division and a voltage scale appropriate to the analyzer's video output level should be selected. With the analyzer still running in the 60-s time trace mode, the oscilloscope triggering level should be adjusted high enough that a trace will be triggered just at the point that the radar's main beam swings past the measurement site. The radar pulse train will now be captured every time the radar aims at the measurement site. The pulse width, pulse repetition rate, stagger, and phase coding of the pulses (if any) can be read directly from the oscilloscope display.

It must be emphasized that it is very important to acquire as many of the radar emission parameters as possible, as these parameters are the only reliable electronic means by which a radar may be identified, and by which other radars may be eliminated from consideration.

When the radar is identified, it may be necessary to measure the radar spurious emissions to determine whether or not the radar spurious emissions comply with the RSEC (see Section 2). Such measurements and analysis may require the resources of a spectrum-management agency. Procedures for such measurements and the application of the RSEC are described in the Appendix.

When a reliable measurement of radar spurious emissions has been performed, another measurement of the extended radar spectrum should be performed through the antenna and RF front-end of the earth station that is experiencing interference. If the interference is occurring as a result of in-band spurious emissions from the radar, then the exact amplitude of the spurious emissions in the earth station system can be unambiguously determined. This measurement of spurious emission amplitude in the earth station can then be used to determine the minimum amount of attenuation that must be provided by one or more of these mitigation measures: RF filtering installed on the radar transmitter output, earth station antenna sidelobe suppression, or earth station site selection.

There is no fixed process for coordination of radar spurious emission interference mitigation. The contingencies that arise in the coordination process must be accommodated on a case-by-case basis. If the radar involved is a Government installation, agencies such as NTIA, the FCC, and the spectrum management section of the agency operating the radar may assist the process.